SIMULATIONS OF DYNAMIC BANDWIDTH ALLOCATION ALGORITHMS

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Abstract: This paper deals with dynamic bandwidth allocation algorithms, which are used in passive optical networks. Deployment of these algorithm is appropriate for efficient use of optical fibers. Work focus on algorithm called Hybrid Reporting Allocation and static allocation tested on own developed simulator for ten gigabit passive optical network. Paper include results from simulations.

Keywords: passive, optical, network, HYRA, dynamic, bandwidth, algorithm

1 INTRODUCTION

Suitability of deployment PON (Passive Optical Network) grows thanks to the increasing capacity and speed requirements. Another plus in use these networks, is still reduce price to build PON. PON have great advantage because it does not require repeaters or otherwise electric powered device along the optical route. XG-PON (gigabit passive optical network) use only one optical wire for upstream and downstream direction. Directions are divided by WDM (Wavelength-Division Multiplexing). In downstream direction transmit only one device. On this direction there is not any collisions between signals of other devices. Problem with collisions can occur in upstream direction, because in this direction every ONU transmit own signal. XG-PON implements TDM (Time Division Multiplex). So ONU device can transmit only in his time slot. DBA (Dynamic Bandwidth Allocation) algorithms dynamically allocate this time slots to every ONU [3, 2].

Deployment DBA algorithms very improve efficiency optical fiber, reach it with static allocation is possible only in few cases. These algorithms used to dynamic allocation bandwidth. So DBA algorithms very help to increase efficiency, that they decrease bandwidth of ONUs that will not use all assigned bandwidth and increase bandwidth of ONUs which has lack bandwidth. In the case of empty ONU's buffer, ONU must send empty frame called idle frame. So there is waste of bandwidth, that could use another ONU. Very heavily utilized ONU which has too small bandwidth must buffer data, that goes to delay in delivery data to recipients. This is big problem for real time services, which are dependent on low delay such as VoIP. When delay is much more, than we expect decreasing user experience, because the call begins to stuck and lag [3, 1, 5].

2 BACKGROUND

DBA algorithms can immediately respond to current ONUs load. For detect current load, respectively current buffer occupancy of each ONU, XG-PON come with two methods [1, 5]:

1. Status reporting (SR) [1, 5]
2. Traffic monitoring (TM) [1, 5]

First method called Status reporting use field in DBRu (Dynamic Bandwidth Report upstream) field in upstream XGTC (XG-PON Transmission Convergence Layer) burst. This field uses ONU to inform OLT about their buffer occupancy. Exact location is in 1, which shows whole upstream XGTC burst [1, 5]. Second method is Traffic monitoring. TM monitor network flow, in which search for occurrence of every idle XGEM (XG-PON Encapsulation Method) frame. Idle frames send ONU when ONU do not have any data to send or ONU have fragmentation violation [1, 5].

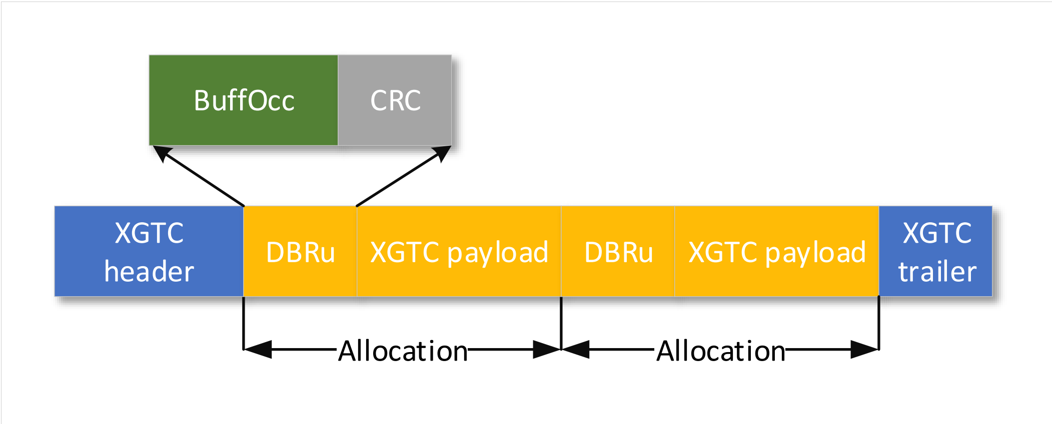

Figure 1: Upstream XGTC burst [1]

Currently there is not so much presented DBA algorithms, and presented algorithms are described very severely. For testing was selected algorithm called HYRA (Hybrid Reporting Allocation). HYRA has been tested together with static allocation. Test was run on specially developed XG-PON simulator for this tests [4].

HYRA allows allocation of three bandwidth types: [4]:

1. **Fixed BW** [4]
2. **Assured BW** [4]
3. **Max BW** [4]

ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) recommends allocate fixed BW independently to current network load. Algorithm HYRA present adaptive learning automate called LA (Learning Automata), which is a machine with a finite numbers of state. Main properties of LA are little complexity, thanks to which applications on computationally weak processors. Next properties are fast convergence and effective efficiency [2, 1, 4].

The whole algorithm is based on three phases. These three phases are applied on all ONUs separately. Status Reporting represent first phase. Here algorithm stay all time that ONU receive data frames from specific ONU. For clarification data frames contains useful data in payload field. Second phase was called TM. To second phase was ONU switched after receive idle frame. During switching to this phase, algorithm remove allocated BW from specific ONU for most likely time and switch to third phase. In third phase stay for time set in previous phase [4].

HYRA used to few numeric values. First is time for remove BW from ONU, called *A*. It may contain value from zero to four hundred. Simply explained it is number of algorithm recalculations in which algorithm not allocate any BW to that ONU [4].

$P^i(f)$ is next value, which algorithm need to work. It is probabilistic vector, which contains up to four hundred values [4].

$$P^i(f) = p_0^i(f), p_1^i(f), p_2^i(f), \ldots, p_{400}^i(f)[4] \tag{1}$$

Where i is ONU order.

Next value which algorithms uses is a_k, which expresses transmission time when specific ONU sends only idle XGEM frames. Values is calculated using this formula [4]:

$$a_k = \lfloor \frac{T2 - T1}{125} \rfloor 0 \leq k \leq 401[4] \tag{2}$$

Where $T1$ is time when first idle XGEM frame arrives and $T2$ is time when first data frame was received after idle XGEM frame. Compute of value $T1$ start immediately after OLT receive $T2$ time. Next is required recompute probabilistic vector. First step to do that is compute increase probability current selected time using this formula [4]:

$$p_k^i(f+1) = p_k^i(f) + \sum_{j=0, j \neq k}^{400} L(p_j^i(f) - a)[4] \tag{3}$$

Where i is current selected ONU, k is current selected time, L used to set speed of convergence. Value a prevents set probability values to zero. Next step is compute decrease of the rest probabilities. For that algorithm uses this formula [4]:

$$p_j^i(f+1) = p_j^i(f) - L(p_j^i(f) - a) \; \forall \; j \neq k, 0 \leq j \leq 400 \tag{4}$$

a	10^{-5}
l	0.1
Fixed BW	6
Max BW	150
Assured BW	125

Figure 2: HYRA parameters

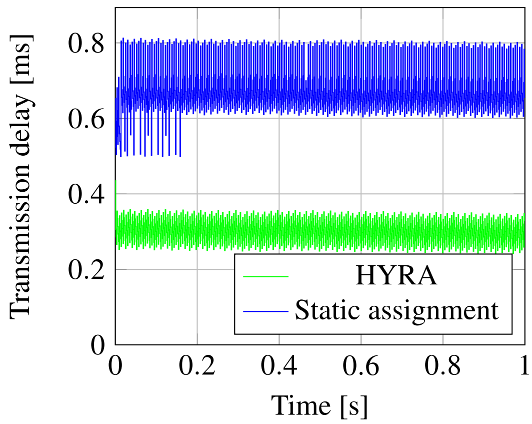

Figure 3: Transmission delay for second ONU

3 SIMULATION DESCRIPTION

For testing in this paper was developed special XG-PON simulator. Simulator was wrote in C++, with using object-oriented programming. Simulator can be controlled thru command line. Figure 4 show network diagram implemented in this simulator. In network diagram can be change thru settings only number of ONUs. Splitter in network diagram is only for illustration, simulator implement ODN (Optical Distribution Network) like one optical wire. Simulator allows settings like simulation time, number of ONUs connected to ODN (Optical Distributed Network), choose between static allocation

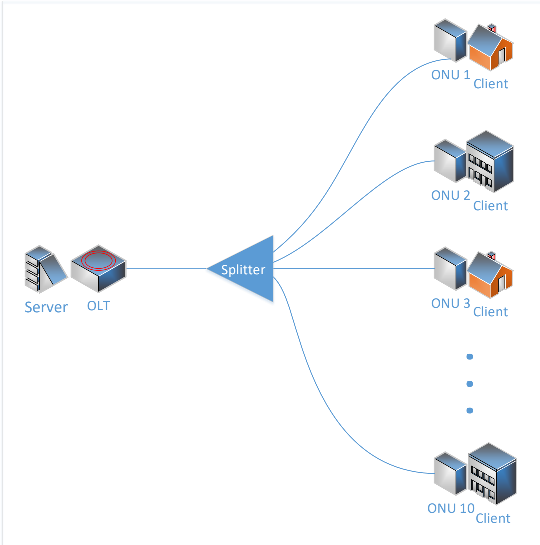

Figure 4: Network diagram

and use HYRA algorithm. For speed up simulation, it not contain full implementation of this network. Parts like frame encryption is not implemented.

In results from simulator are all allocated grants to all ONUs. Times in which ONU generates idle frame, transmission delay from ONU to OLT and back. Last two values are statistical. First contains average delay, and second overall idle frame size. Fixed BW is set to specific value and it is not changed in all time. So focus simulation is to Assured BW. Simulation time was set to 1 s and number of ONUs connected to ODN was set to 10. HYRA parameters are shown in Figure 2.

Static allocation was set to allocate 242 words, for all Alloc-IDs on every ONU. Simulator automatically compute maximal BW assignment according to number of ONUs. Second run contains HYRA algorithm, where a, l and assured BW was set as propose in [4]. All values are in 2. This algorithm is dynamic, so it allocate BW based on current load of each ONU.

4 RESULTS

In some transmission delays such as on second ONU, can be clearly visible learning time of HYRA algorithm. This simulation periodically send 1000 kb useful data. Figure 3 show transmission delay from second ONU, where is visible that for this simulation settings, HYRA algorithm need less than 200 ms to learn probabilities. After that HYRA correctly determines situations and jitter decrease. In other hands average, minimal and maximal delay will increase, but for example minimal delay increased by 100 us. This number is very small, so it has no bad influence to network flows.

Figure 5 show BW allocation for second Alloc-ID of first ONU. For better clarity graph show maximal time 50 ms. Generated data flow and HYRA settings cause that buffer occupancy reach maximum allocation so HYRA allocate max BW. On other hand emptied is fast, so buffer occupancy go to zero and HYRA allocate only 1 word, which is needed for sending frames with buffOcc field, for report current buffer occupancy.

Figure 6 show size of idle frames generated by first ONU. This figure show also maximal time 50 ms for better clarity. There is clearly see that static assignment compare to HYRA has allocated unnecessarily much BW. So it is clearly see that static assignment wastes BW. HYRA wastes BW, but approximately half less.

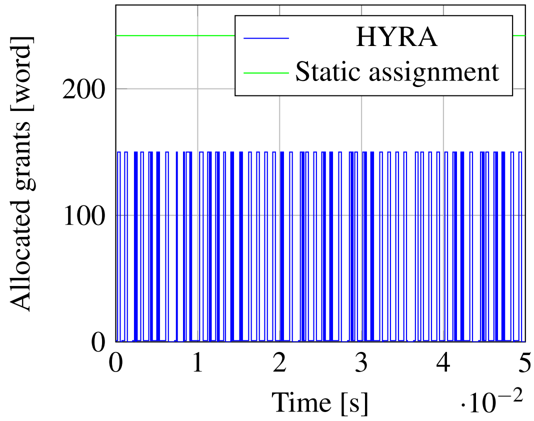

Figure 5: Allocated grants for first ONU

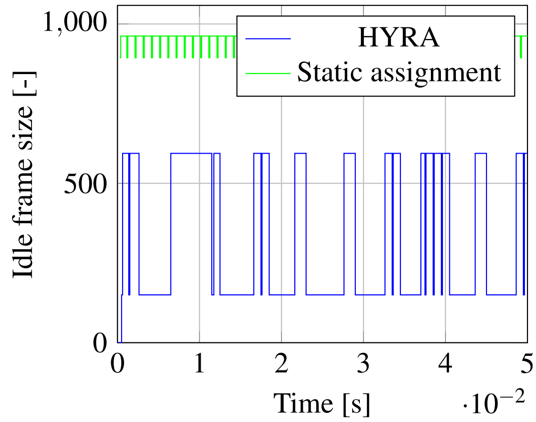

Figure 6: Idle frames for first ONU

5 CONCLUSION

Static assignment is good in networks where OLT transmit usually same data size, and data size is not increase max BW assigned to ONU. For 10 ONUs, 1 ONU can max transmit frames with size 242 words. Larger will increase transmission delay, because frames must be buffered. Today networks has very different network flow in every time in day, so static assignment is not good for that networks. HYRA reliably responds to network flow change, so it good to networks with different network flows. But HYRA algorithms little increase delay.

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